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CARDIOVASCULAR HEALTH STATUS, AGE, AND PSYCHOLOGICAL PERFORMANCE

OFFICE OF AVIATION MEDICINE
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Cardiovascular Health Status, Age, and Psychological Performance[1]

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An important problem in the psychology of aging is the extent to which poor or slow performances are associated with age-correlated, controllable diseases rather than with "aging" *per se*. Several published studies (see Discussion) indicate that middle-aged men with essential hypertension or coronary heart disease perform more poorly than like-aged controls on a variety of tests and tasks. The present study contrasts task performance scores of healthy men with scores of men who live normal lives and are in nominally "normal" health, but who have cardiovascular diseases with mild to moderate degrees of symptoms. The scores of men who presented histories or symptoms of cerebrovascular involvement are treated separately.

Materials and Methods

Subjects.—Federal law requires that civil aviation pilots and air traffic control specialists pass physical examinations periodically in order to practice their specialties. Persons needing physical certification may go to any of about 6,000 private physicians in the country who are licensed to certify them, or to the Federal Aviation Agency's Georgetown Clinical Research Institute in Washington, D. C., where these data were gathered. Also, men who are refused certification by a private physician may receive an "appeal" examination at this Clinic. Men were assured that they would be judged only on the standard, legally-prescribed physical examination, and were asked to volunteer for the more elaborate research tests and measures, including the psychological tests. Fewer than 1% declined. Most of the volunteers were FAA employees and most are or have been pilots or air traffic controllers, or both. Nearly all come from the highest one-fourth of the population in terms of occupational status and education. Approximately one-half were given the WAIS Arithmetic and Vocabulary scales (Wechsler, 1955); almost none scored below the population mean, and most fell one standard deviation or more above it on both scales. The majority of these *Ss* were admitted to training in their aviation specialties on the basis of entrance test-batteries, which usually contained tests of both perceptual-motor speed and spatial form-perception abilities. All *Ss* were between the ages of 23 and 59; most of *Ss* of major interest in this study fell in the age range 35-59. All were white. From nearly 800 dossiers of *Ss* aged 59 or younger, the Institute's neurologist or other examining physicians eliminated most *Ss* who showed appreciable symptoms of central neuropathology. Most *Ss* with other miscellaneous pathological conditions were also eliminated. A cardiologist, W. R. Scarborough, M.D., of this Clinic, formed the following groups from the remaining dossiers:

Ia. Strictly healthy *Ss* (N=560) all of whom actively volunteered to come to the Clinic. None had been referred by another physician. Of these, 339 were aged 35-59.

Ib. "False Positive" *Ss* (N= 16) who had been referred to the Clinic for further evaluation and were thus extremely concerned about the outcome of the examinations, but were later judged sufficiently healthy to fly or work air traffic control positions.

II. *Ss* (N=22) with stable mild rheumatic or congenital cardiovascular defects. Many of these were active volunteers, although some were referred.

IIIa. *Ss* (N=47) with somatic arteriosclerotic or coronary heart disease. All were mild or moderate cases; that is, all fell into American

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Heart Association categories IA or IB. All were referred to the Institute by other physicians. All were normotensive, and none showed independent clinical evidence or history of cerebrovascular disease or impairment. A majority had evidence and histories of myocardial infarction, none less than 6 months prior to the examinations. All were recovered and regularly employed.

IVa. Ss (N=17) with hypertension or hypertensive cardiovascular disease in mild or moderate degree (AHA class IA or IB), with blood pressures persistently higher than 140/90. None showed clinical evidence or histories of cerebrovascular disease or impairment.

V. Ss (N=9) presenting history or clinical symptoms of cerebrovascular disease.

None of the foregoing Ss had taken drugs on the day of the examination or for several days before the examination, and most had not taken drugs for several weeks or more before the examination.

Most individuals in group Ia were volunteers who had no particular reason to be anxious in the clinical situation. In contrast, many of the individuals in Groups Ib, IIIa, IVa, and V, and some in Group II had reason to be anxious or emotionally troubled about the outcome of their physical examinations, although those few who seemed emotionally upset were excluded from this study.

In order to control for possible differences in the emotional states between Ss in Group I and in the other aforementioned groups, volunteers were recruited from fully employed FAA officials who were not seeking medical certification, through the kind cooperation of Bernard J. Kramer, M.D. They were enrolled in an independent, executive health program and had been diagnosed by Dr. Kramer as suffering some cardiovascular disease with mild or moderate symptoms (AHA categories IA or IB). Almost 100% cooperation was obtained. Unfortunately, the small size and the heterogeneity of this sub-population permitted the formation of only two groups:

IIIb. 12 individuals with history and evidence of old myocardial infarctions, coronary heart disease or arteriosclerosis, without hypertension. None had taken drugs for several weeks preceding the tests.

IVb. 13 individuals who had been diagnosed as hypertensive by private physicians or at the independent executive health clinic, and whose blood pressures were being kept below 140/90 at the time of testing by various drug treatments. Two took central nervous system depressants and the others took vasodilating drugs.

None of the Ss in Groups IIIb or IVb had histories or symptoms of cerebrovascular disorders. They were given only the psychological tests, without physical examination, at this Clinic.

All Ss in Groups IIIa, IIIb, IVa, IVb, and V were 35-59 years old.

Tests.—Ss were given the following tests, usually in a single session, in order 1, 2, 3, and also were given tests 4 and 5 when possible.

1. WAIS Digit-Symbol Substitution Test (Wechsler, 1955). An earlier version of this test was found to be a good indicator of organic brain dysfunction (Reitan, 1955).

2. Trail Making Tests A and B, which are good indices of organic brain impairment (Reitan, 1958).

3. A battery of stimulus-matching, serial reaction-time tests on the Psychomet Apparatus (Birren, Riegel, & Morrison, 1962), with the original tests 2-9, plus several new variations. The device has a 14″-wide row of 10 stimulus windows in front of the *S*, with 10 response buttons in a corresponding row a few inches lower, and labels just above the buttons. In all tasks, when the *S* pressed the "start" button, a stimulus window lighted and gave a cue indicating which of the 10 buttons should be pressed. When *S* pressed the correct button, it extinguished the stimulus and simultaneously lighted another one, etc., to make a continuous serial choice reaction-time task. A subtest consisted of two sets of 10 reactions. The tests were I) pressing the button directly under the stimulus light; II) finding the button labeled with stimulus digit "j" and pressing it, when the 10 buttons were labeled in order—1, 2, 3, . . j . . 10; III) like II, but with the buttons labeled in a scrambled order; IV) and V) like II and III, with letters rather than digits; VI) and VII) like III and IV but with large (5/8″) block symbols; VIII) stimulus-matching as above, but with a stimulus one of five colors with either an "X" or an "O" in it; IX) matching Y-shaped patches, with a red, a yellow, and a blue pie-shaped segment in each.

In all of the above tests, *S* was told to go as fast as possible. A previous factor analysis of some of these data (Birren & Spieth, 1962) indicated that all three sets of tests loaded heavily on a single "speed" factor, so the scores were all weighted appropriately and added to produce a single "composite speed score."

4. The Halstead Tactual Performance Test (Halstead, 1947; Reitan & Shipley, 1963). This test is an excellent indicator of organic brain impairment (Reitan, 1959).

5. The WAIS Block Design Test (Wechsler, 1955) with *Ss* given sufficient time to complete all items. This test is a modification of an earlier one, the WB-I Block Design Test, which is a good indicator of organic brain impairment (Reitan, 1959).

Results

Speed tests.—The composite speed scores (weighted sum of standard Psychomet Tests, Trail Making Tests, and WAIS Digit Symbol Test) of *Ss* in Groups Ia, IIIa, IIIb, IVa, and IVb are shown in Figure 1, by age, together with lines connecting their means. Groups IIIa and IIIb (arteriosclerotic disease groups) are plotted as a single group. The ordinate values correspond to the standard deviation for all healthy *Ss'* scores.

Because most of these various subgroups were rather small and were irregularly scattered among the various age levels and because the variance of the various health groups seem to be heterogeneous, the differences between means of the healthy group and each of the groups with pathological conditions were tested in the following manner: a straight line was fitted to the means of the healthy *Ss* aged 35-59. This line was taken as the "baseline" for all scores in the 35-59 age range; that is, this line defines a score of "zero" in all of these age levels for all *Ss*, healthy or otherwise. The variance of healthy *Ss* aged 35-59 around this line was computed and called unity. The mean and standard deviation of the healthy *Ss* thus were 0.00

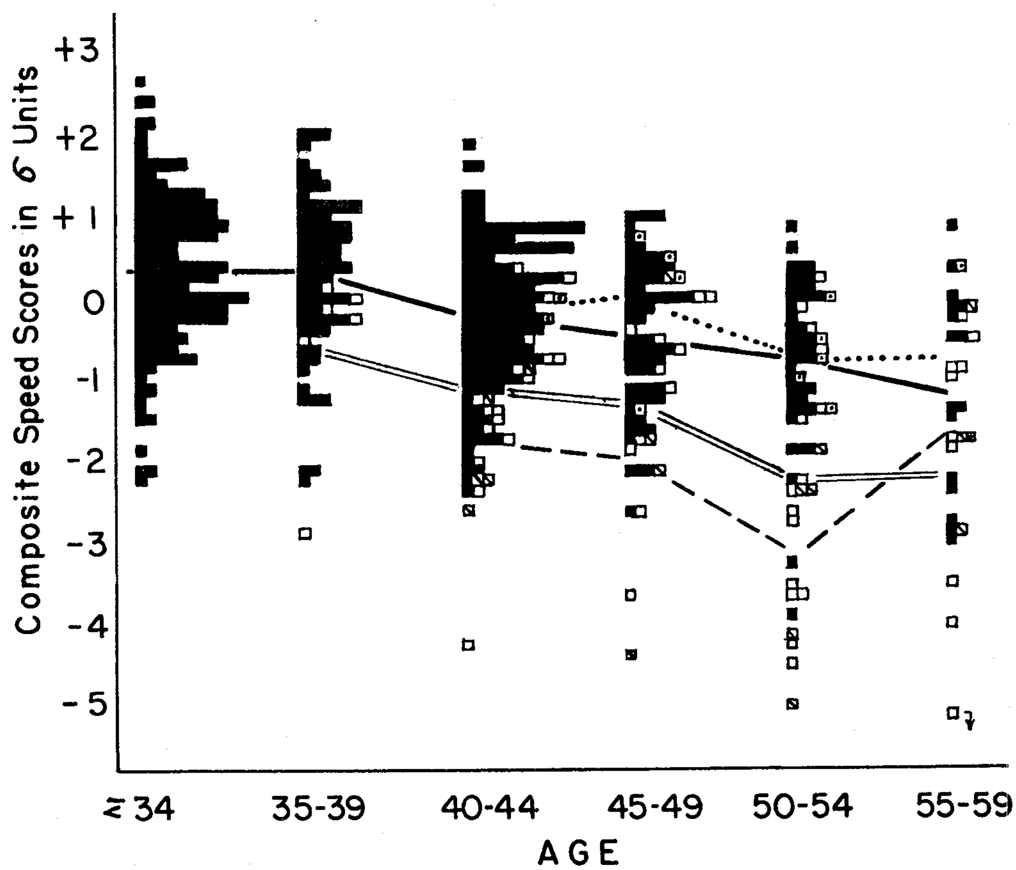

Fig. 1. Distributions of individual composite speed scores (in σ units) by age for healthy *Ss* (■ ——— ■), Groups IIIa and IIIb combined (□═══□), Group IVa (⧅ —— —— ⧅), and Group IVb (⊡ . . . . . . ⊡).

and 1.00 by definition. Table 1 gives the composite speed test results in these terms.

The 22 individuals with congenital or rheumatic heart-defects were slower than the healthy individuals, but not significantly so.

Both groups of Ss with non-hypertensive cardiovascular diseases (Groups IIIa and IIIb) were very significantly slower than the healthy group and very similar to each other.

The hypertensive Ss showed a more complicated picture: Group IVa, Ss who were not medicated and presumably susceptible to situational stress, were at least as slow as the arteriosclerotic Groups IIIa and IIIb. In contrast, the hypertensive volunteers, who were medicated and presumably less liable to possible situational stress, performed as well as the healthy group.

The nine cerebrovascular Ss performed most slowly of all, as would be expected. It is interesting that the unmedicated hypertensive Ss (Group IVa) were almost as slow as these cerebrovascular cases.

All subgroups listed in Table 1 were faster than would be exected on the WAIS Digit Symbol Test. The WAIS Manual gives conversion scales for various adult ages, so that the performance of each age group in the large standardization samples has a mean of 10.0 and a standard deviation of 3.0. In these terms, our healthy Ss aged 35-59 had mean Digit Symbol scores of 13.2, or slightly more than one standard deviation above the population mean score; cardiovascular Groups IIIa, IIIb, and IVa considered together had a mean score of 11.1 points. The estimated standard deviations of the scores of various groups of Ss with pathological conditions were no greater than the population standardard deviation of 3.0, while the standard deviation for the healthy individuals was considerably less: about 1.8 points instead of 3.0. Because a previous study (Birren & Spieth, 1962) showed correlations of about 0.40-0.65 between the Digit Symbol Test and the other, very brief, speed tests in the battery, it seems safe to conclude that our aviation sub-population is superior to the population at large on speed tests in general.

The relative discriminative powers of the various speed tests were assessed by *t*-tests between mean scores on individual tests of the healthy group versus Groups IIIa, IIIb, and IVa combined, the healthy group versus the cerebrovascular group (both sets of tests used age-adjusted scores), and young healthy Ss (ages 23-39) versus old healthy Ss (age 50-59). The Psychomet Stimulus-matching Tests

Table 1. Age-adjusted Composite Speed-test Scores for All Subjects Aged 35-59.

Group	N	Mn (Std. Score)	σ	P
Ia. Healthy volunteers	339	0.00	1.00	
Ib. "False positives," maximally stressed healthy cases	16	−0.06	0.98	>0.50
II. Rheumatic or congenital defects, compensated, AHA class IA	22	−0.38	1.07	>0.10
IIIa. Arteriosclerotic cardiovascular disease, AHA class IA or IB (mild or moderate, compensated), not medicated, some situational stress	47	−0.95	1.43	<0.001
IIIb. Arteriosclerotic cardiovascular disease, AHA class IA or IB, not medicated, volunteers not under situational stress	12	−1.54	1.53	<0.01
IVa. Essential hypertension, AHA class IA or IB, not medicated, some situational stress	17	−1.74	1.40	<0.001
IVb. Essential hypertension, AHA class IA or IB, medicated, volunteers not under situational stress	13	+0.24	0.77	>0.10
V. Individuals displaying history or physical evidence of cerebrovascular disease, recovered and without overt mental/behavioral deficits	9	−1.97	1.24	<0.01

Table 2. Average Length of the Speed Tests and *t*-values of Mean Differences in Reaction Times Between Various Subgroups.

Tests or Combinations	Av. Time for Healthy Aged 40-44 (Sec.)	Healthy vs. Gps. (IIIa+ IIIb+ IVa) (*t*)	Healthy vs. Cerebrovascular Ss (*t*)	Young (age 23-39) vs. Old (age 50-59) (*t*)
I. Psychomet Tests				
1. Simple light matching, sum of 4 runs of 10 responses	28	6.44[b]	1.85	3.29[a]
2. Small digit or letter matching, buttons labeled in order	45	5.63[b]	4.72[b]	8.11[b]
3. Small digit or letter matching, buttons labeled in random sequence	64	7.47[b]	5.66[b]	10.78[b]
4. Large digits or letters, buttons labeled in scrambled sequence	55	6.24[b]	5.87[b]	8.46[b]
5. Color-plus-symbol stimulus matching	45	5.77[b]	2.68[a]	7.89[b]
6. Tri-color stimulus matching	90	3.51[b]	2.25	1.94
II. WAIS Digit-Symbol Test	90	4.84[b]	3.31[b]	6.33[b]
III. Trail Making Tests A+B	86	4.73[b]	3.16[a]	3.70[b]

[a]Statistically significant at less than 0.01 level of confidence.
[b]Statistically significant at less than 0.001 level of confidence.

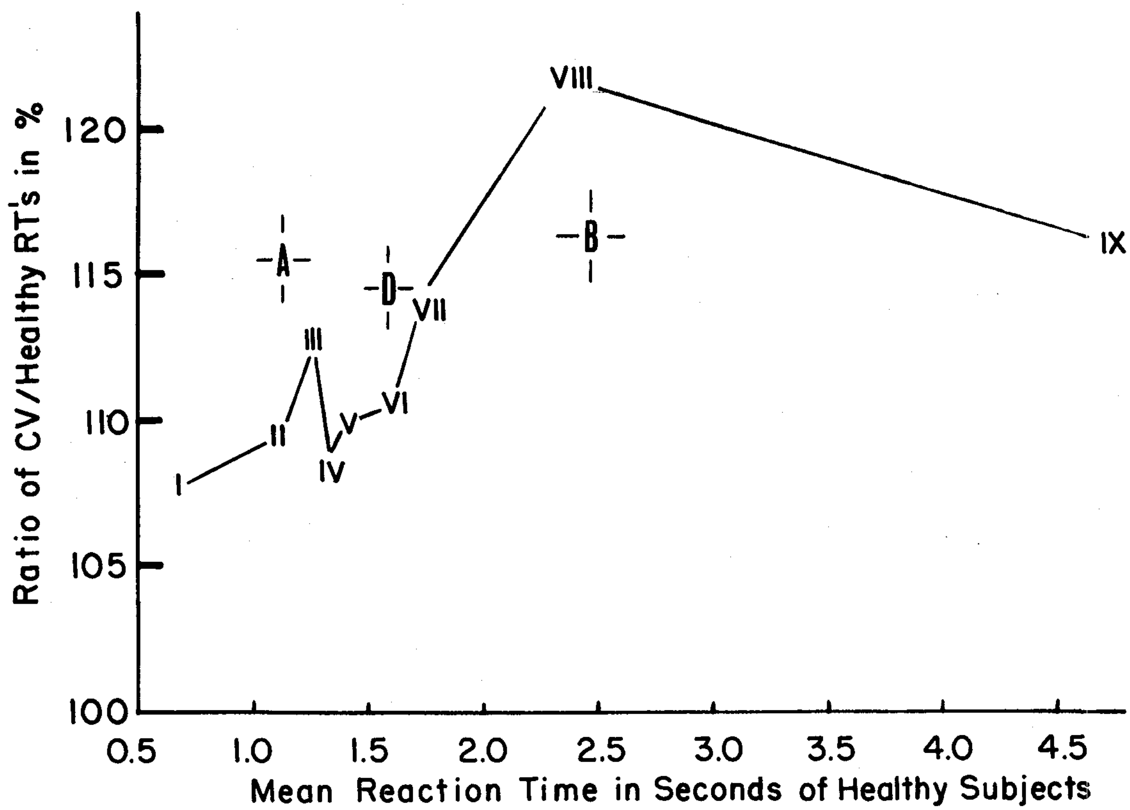

Fig. 2. The abscissa represents the mean time required by a healthy *S* per reaction in a serial choice reaction time test, or per response in a paper and pencil test. The mean time per reaction by *Ss* in Groups IIIa, IIIb, and IVa combined is plotted as a percentage of the mean time per reaction on the test by a healthy *S*. I———IX Psychomet Tests; A, B—Trail making tests; D, digit symbol test.

Table 3. Mean Performances on the TPT and Block Design Tests for Healthy Subjects and for Subjects with Cardiovascular Disease (Groups IIIa, IIIb, and IVa Combined).

		Tactual Performance Test					Block Design Test		
Age (Yrs.)		N	Total[a] Time (Sec.)	Time[a] 3rd Trial (Sec.)	Shapes Recalled	Locations Recalled	N	WAIS Point Score	Time[a] (Sec.)
20-34	Healthy	146	480	85	7.7	5.7	145	41.8	250
	CV	—	—	—	—	—	—	—	—
35-39	Healthy	74	474	94	7.7	5.5	83	43.7	245
	CV	4	643	149	5.5	3.2	3	41.0	450
40-44	Healthy	143	530	109	7.4	4.7	122	41.0	291
	CV	19	575	112	7.4	5.0	14	36.8	378
45-49	Healthy	55	590	116	7.6	4.8	57	38.6	340
	CV	10	710	168	6.1	2.7	10	39.3	370
50-54	Healthy	38	625	123	7.1	4.1	38	38.8	372
	CV	16	830	164	6.4	3.6	15	36.0	410
55-59	Healthy	13	758	167	6.2	3.9	19	39.1	340
	CV	12	835	200	6.8	3.1	9	33.0	534
Means of Cerebrovascular Ss and healthy Ss of same age distribution	Healthy	249	595	118	7.4	4.6		38.8	350
	CV	9	878	208	6.2	3.4		35.9	485

[a]Time scores are geometric means, in seconds.

(scrambled large or small digits or letters, or colors-plus-symbol) and the Digit-Symbol Test all were reliable discriminators in all comparisons; the Trail Making Tests were less so, especiallly for age. Because of the extreme brevity of some of these tests, some pairs of tests were combined to make scores, which in most cases were based on at least 40 seconds of performance. These combinations and their associated t-values for various comparisons are shown in Table 2. The health-status comparisons are based on age-adjusted scores. Old healthy *S*s were slower than young healthy *S*s, and *S*s with pathological conditions were slower than like-aged healthy *S*s on all tests.

The relative slowing of the *S*s with cardiovascular diseases (Groups IIIa, IIIb, and IVa) is shown in Figure 2. The Psychomet Tests are represented by Roman numerals connected by lines, and the paper and pencil speed tests by letters. As may be seen, the *S*s with cardiovascular disease tended to take a disproportionately longer time than normal *S*s on the more complex reactions.

The Halstead Tactual Performance Test (TPT).—Four scores were derived from TPT performance: total time required to complete the task three times, time required on the third trial, and also number of shapes, and number of locations drawn in the untimed recall test which followed the three completions of the tactual task. The means of these scores by age and health categories are shown in Table 3.

The *S*s with cerebrovascular disease (Group V) were significantly poorer than like-aged healthy *S*s on all measures. F-tests were performed, using only *S*s aged 35-59, between the healthy group, and Groups IIIa, IIIb, and IVa combined to form a single group. (It was apparent by inspection that the *S*s with rheumatic-congenital defects [Group II] and the medicated hypertensive volunteers [Group IVb] were not significantly different from the healthy group.) The F-test technique used (Snedecor, 1946) takes account of the disproportionate age distribution of number of cardiovascular and healthy *S*s. There was a highly significant increase, with age, in total time required ($P < 0.001$) and in time required on the third trial ($P < 0.005$). Older *S*s recalled significantly fewer block shapes ($P < 0.002$) and insignificantly fewer block locations ($0.20 > P > 0.10$) than younger *S*s.

The combined group of *S*s with cardiovascular pathological conditions compared with healthy *S*s, required significantly more total time ($P < 0.025$), and were slower on the third trial, but at a borderline level of statistical significance ($P < 0.05$). They recalled fewer block shapes, at a borderline level of statistical significance ($P < 0.05$), and were insignificantly poorer at recalling block locations ($0.20 > P > 0.10$) in comparison with the healthy *S*s.

Modified WAIS Block Design Test.—Mean performance scores are given in Table 3. The healthy *S*s' scores averaged more than one standard deviation above the estimated means for the whole population at various ages as given by the quite extensive standardization data (Wechsler, 1955) for this test. The performance of the cardiovascular *S*s, while below that of the healthy *S*s of like age, averaged almost a full standard deviation above the population mean. No attempt was made to analyze mean differences among these point scores because of the pronounced ceiling effect in the distribution of these scores. In order to obtain continuously-distributed measures, each *S*'s score was taken as the logarithm of the sum of times required to perform the last four (and most difficult) items on this test. Groups Ib, II, and IVb performed very like the healthy *S*s. Groups IIIa, IIIb, and IVa combined were compared with healthy *S*s aged 35-59 in a health-by-age F technique which corrects for disproportionalities of age by health category (Snedecor, 1946). The increase of the time score with age was significant ($P < 0.001$), and the cardiovascular *S*s were slower than like-aged healthy *S*s at a borderline level of statistical confidence ($P<0.05$).

Discussion

Could these results be attributed to different degrees of stress which the clinical testing situation may have produced in members of different subgroups? I think they could not, at least for the normotensive individuals: the "false positive" *S*s in Group Ib, who had the most reason to be emotionally distressed by the clinical situation, performed as well as the large comparison Group Ia, while among the normotensive arteriosclerotic *S*s, the presumably more relaxed members of Group IIIb performed as poorly as did the presumably more stressed members of Group IIIa.

No simple conclusion can be drawn from this study about the effects of hypertension on performance. The untreated hypertensive *Ss* in Group IVa had reason to be under considerable situational emotional stress and performed quite poorly; the essentially hypertensive members of Group IVb, whose blood pressures were being kept within normal limits by drug treatments, and who also were tested under presumably more relaxed circumstances, performed as well as the healthy control group. It is plausible (Spieth, 1964) that both emotional stress and blood pressure were causal variables in this study.

Does the slowness of the cardiovascular *S*'s performance reflect a "basic" or "fundamental" reduction in mental efficiency, or merely a more cautious self-pacing? I think the former is true, for these reasons: a) Most of the cardiovascular *Ss* in this study hoped to demonstrate themselves as fit to fly or control air traffic. b) The cardiovascular disease Groups IIIa, IIIb, and IVa were somewhat poorer than like-aged healthy *Ss* on the untimed recall parts of the Halstead Tactual Performance Test—significantly so at recalling the shapes of the blocks. This recall test was truly free of speed effects, because each *S* was given whatever time was necessary to reach the performance criterion before the untimed recall test began. c) In the Psychomet Test battery, there was a clear-cut, health-group by subtest-complexity, interaction of reaction times. All Psychomet Subtests were performed on the same stimulus and response-button panel. The stimulus-oculomotor and the arm-motor activity were the same in all subtests, while the complexity of the information-processing varied considerably. If simple "motor" slowing were all that were involved, we would expect the ratio of reaction times of healthy to cardiovascular *Ss* to decrease from the less to the more time-consuming tasks, while in fact the reverse occurred, as may be seen in Figure 2. The mean RT of the cardiovascular *Ss* on the simplest Psychomet test was about 0.05 second longer than the mean RT of healthy *Ss*, while on the more complex tests the cardiovascular *Ss* took several tenths of a second longer per reaction than did the healthy *Ss*. Thus most, and possibly all, of the slowness of the cardiovascular *Ss* on the more complex subtests came not in the "doing," but in the "deciding what to do" phase of the reaction process. This fact does not refute the "self-pacing" hypothesis of cardiovascular *Ss*' slowness, but it does, I believe, weaken the case for it somewhat. d) Outside evidence counter-indicates a "self-pacing" hypothesis: A set toward slowness would not seem to explain the findings by Simonson and Enzer (1941) of subnormal flicker fusion thresholds in *Ss* with hypertension and/or coronary heart disease, nor Reitan's (1954) finding of significantly more numerous "organic signs" in hypertensive *Ss* than in controls on the untimed Rorschach test. The most interesting indirect information comes from Anderson's (1963) finding that coronary heart disease *Ss*, while they performed more slowly than control *Ss* on a speeded test, also made more errors: one would expect fewer errors from a set or attitude toward limiting one's pace.

The data in this study further confirm several other studies which indicate that middle-aged individuals with coronary heart disease or hypertension perform more poorly than control *Ss* on a variety of psychological tests and tasks, probably even when there is no independent evidence of cerebrovascular impairment. In addition to the aforementioned studies, Enzer, Simonson, and Blankstein (1942) reported that *Ss* with coronary heart disease and/or hypertension had a lower maximum finger-tapping rate than healthy *Ss* of like age; this reaction they ascribed to circulatory insufficiency. Apter, Halstead, and Heimburger (1951) found that essential hypertensive *Ss* showed significantly higher indices of organic brain impairment than controls, when the highly valid Halstead Impairment Index battery was used. Birren, Butler, Greenhouse, Sokoloff and Yarrow (1963) reported that elderly hypertensive *Ss* showed slower serial choice reaction times than healthier old *Ss*. Reitan and Shipley (1963) reported a relationship between cholesterol level and performance deficits in old men but not in young men on a battery of tests known to be a sensitive index of brain impairment.

The importance of the present study, if any, is that performance deficits were found in *Ss* who were fully recovered from an acute illness, who presented no history or independent symptoms of cerebrovascular disorder, and whose cardiovascular disease symptoms were rated by cardiologists as "mild" or "moderate" (Classes IA or IB by American Heart Association Standards).

The results of this study do not prove that individuals with moderate degrees of cardiovascular disease are mentally impaired in any gross sense. On the WAIS Digit Symbol and Block Design tests, for which standardization data are available (Wechsler, 1955), these cardiovascular disease Ss, while inferior to the healthy Ss, still did substantially better than would be expected from like-aged individuals drawn at random from the whole population.

The major import of the present results is that substantial parts of the mean "age changes" found in cross-sectional studies of psychological performance might better be attributed to disease processes which are not inexorably bound up with age, but are merely positively correlated with age than to age itself. The incidence of cardiovascular diseases and their increase with age are high enough to account for much of the reported downward trends of mean psychological test scores with age. For example, White, Edwards, and Dry (1950) reported important degrees of coronary arteriosclerosis in about 20% of males aged 35, 50% of those aged 45, and 75% of those aged 55. The incidence curve declines with age after 55 because of a rising death rate. It need be assumed only that the progressively older age samples in a typical study of psychological performance contain progressively higher percentages of the kind of mild-to-moderate cardiovascular disease Ss studied here, in order to predict an appreciable part of the typical "aging effect."

There is no reason at present to conclude that downward trends of performance with age after maturity are entirely attributable to extrinsic disease processes; on the contrary, the strictly healthy Ss in the present study produced mild downward age trends as may be seen in Figure 1 and Table 3. Nevertheless, it would almost certainly be extremely profitable to measure the cardiovascular health status of Ss in any psychological study of aging.

Summary

Psychological performance tests were given to more than 600 men aged 23-59. All were in nominally normal health. Mild to moderate degrees of cardiovascular disease, with apparent cerebral involvement, were reliably associated with slow and, to a lesser extent, poor performance. It is concluded that this was not an artifact of attitude or testing situation. Because cardiovascular disease is common in old humans and its incidence increases very rapidly after age 35, it is suggested that much of the typical downward trend of performance with age is a reflection of cardiovascular diseases rather than of aging *per se*.

The author is grateful to Miss Sue Watkins for administering these tests to the majority of the Ss, to Miss Ann Alderman for performing the statistical tests, and to John Seipel, M.D., neurologist, for identifying neuropathological Ss, so that they could be eliminated from the study or assigned to the relevant subgroup.

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